KINEMATIC ION IMPLANTER ELECTRODE MOUNTING

FIELD OF THE INVENTION

[0001] This invention relates to ion implanters for implanting ions into substrates, such as semiconductor wafers, in electronic device fabrication, and in particular to ion implanters capable of processing wafers on a commercial scale.

BACKGROUND

[0002] Ion implantation techniques are commonly used as one of the processes employed in the manufacture of integrated circuits, to modify the electrical transport properties in predefined regions of a semiconductor material by doping these regions with a predetermined concentration of impurity atoms. The technique generally involves generating a beam of a preselected specie of ions and directing the beam towards a target substrate. The depth of the ion implant depends, inter alia, on the energy of the ion beam at the substrate. As the density of devices on a single wafer increases and the lateral dimensions of individual devices decrease for ultra-large scale integrated circuits (ULSI), the ability of an ion implanter to form shallow junctions using low energy ions, e.g. of about 2 keV to 10 keV, becomes increasingly useful. At the same time, in commercial ion implantation, it is often also useful to be able to process an individual wafer in as short a time as possible and this requires the ion beam current to be as large as possible.

[0003] U.S. Pat. No. 5,932,882 describes one prior technique in which an ion beam is transported at high energy and then decelerated to a lower energy just before the beam impacts the substrate. The ion implanter of this reference comprises an ion beam generator which includes a source of ions and an extractor electrode assembly for extracting the ions from the source and forming a beam of ions. The extraction electrode assembly comprises one or more electrodes which typically have apertures through which the ion beam is shaped. A flight tube transports the beam from the extraction assembly at a transport energy, and a substrate holder holds a substrate to be implanted with beam ions. A deceleration potential generator connected to apply a deceleration potential to a deceleration lens assembly between the flight tube and the substrate holder decelerates beam ions to a desired implant energy. The deceleration lens assembly located between the flight

tube and the substrate holder comprises a plurality of electrodes which typically have apertures through which the ion beam passes.

[0004] The positioning of electrodes such as the extraction electrodes relative to the other parts of the ion implanter can affect the characteristics of the ion beam including beam energy, beam size and beam shape. To align the extraction electrodes of the ion implanter, various devices have been proposed. For example, special set up tools or jigs have been used to align the electrodes for installation into the extraction electrode assembly. These set up tools have often included dowels or other alignment surfaces which are received in corresponding alignment apertures of the electrodes. Each electrode upon being aligned using the setup tool is typically fastened in place within the extraction electrode assembly using suitable fasteners such as screw fasteners. The setup tool is then removed from the extraction electrode assembly. This procedure is typically repeated each time the electrode is replaced.

SUMMARY OF ILLUSRATED EMBODIMENTS

[0005] A kinematic electrode mount is provided for an ion implanter in which an electrode insert member having an electrode body portion which defines an aperture, is inserted into an electrode support frame. In one embodiment, a first kinematic alignment pin of the insert member engages a first, groove-shaped kinematic alignment surface of the electrode support frame to align the first alignment pin in two orthogonal directions relative to the electrode support frame. In addition, a second kinematic alignment pin of the insert member engages a second kinematic alignment surface of the electrode support frame to align the insert member in a rotational orientation relative to the electrode support frame. A plurality of flanges of the insert member engage the electrode support frame to retain the insert member in the aligned position and to electrically couple the electrode insert member to the electrode support frame. A spring positioned between the electrode insert member and the electrode support frame biases the electrode insert member in the aligned and retained position relative to the electrode support frame.

[0006] There are additional aspects to the present inventions. It should therefore be understood that the preceding is merely a brief summary of some embodiments and aspects of the present inventions. Additional embodiments and aspects of the present inventions are referenced below. It should further be understood that numerous changes to the disclosed embodiments can be made without departing from the spirit or scope of the inventions. The preceding

summary therefore is not meant to limit the scope of the inventions. Rather, the scope of the inventions is to be determined by appended claims and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

Examples of embodiments of the present invention will now be described with reference to the drawings in which:

FIG. 1 shows a schematic diagram of an ion implanter employing a kinematic electrode mount according to an embodiment of the present invention;

FIG. 2 shows an exploded view of kinematic electrode mounts in accordance with various embodiments;

FIG. 3 shows a plan view of one embodiment of a kinematic electrode mount of FIG. 2;

FIG. 4 shows a cross-sectional view of another embodiment of a kinematic electrode mount of FIG. 2;

FIG. 5 shows a cross-sectional view of the kinematic electrode mount of FIG. 3;

FIG. 6 shows a plan view of the kinematic electrode mount of FIG. 4; and

FIG. 7 is a cross-sectional view of an alignment pin of the kinematic electrode mount of FIG. 6 as shown along the lines 7-7 of FIG. 6.

DESCRIPTION OF ILLUSTRATED EMBODIMENTS

[0008] An ion implanter in accordance with one embodiment is indicated generally at 1 in FIG. 1. The ion implanter 1 comprises an ion beam generator 3 for generating a beam of ions. A magnet 5 adjacent the ion beam generator spatially resolves the beam ions according to their mass. An ion selector 7 disposed adjacent the analyzing magnet 5 selects a specie of ions to be implanted into a target substrate and rejects other ions in the spatially resolved beam from the magnet. An electrode assembly 9 disposed adjacent the ion selector 7 controls the final energy of the ion beam before implantation. A support or holder 11 spaced from the electrode assembly 9 supports a target substrate 12 to be implanted with beam ions. An electron generator 13 disposed between the electrode assembly 9 and the substrate support 11 introduces electrons into the ion beam near the target surface to neutralise the beam and wafer surface. An ion beam collector 14 positioned downstream of the substrate support 11 serves as a beam stop and ion current detector for dosimetry measurements.

[0009] In more detail, the ion beam generator 3 comprises an ion source 15 including an arc chamber 17 having an exit aperture 19 formed in the front face thereof. An extraction electrode assembly 20 includes a pair of extraction electrodes 21, 23 which are spaced from the exit aperture 19. The extraction electrodes 21, 23 of the assembly 20 extract ions from the arc chamber and form an ion beam 25. The extraction electrode 21 which is closest to the exit aperture 19 of the arc chamber serves as a suppression electrode to prevent electrons forward of the beam generator from flowing to the arc chamber. As explained in greater detail below, the extraction electrode assembly 20 includes a kinematic mount which permits each electrode 21, 23 to be readily mounted in place in a closely controlled aligned position without the need for realignment each time an electrode aperture is replaced. Although described principally in connection with the extraction electrodes, 21, 23, it is appreciated that a kinematic mount in accordance with these embodiments may be used to mount other electrodes of an ion implanter including the deceleration electrodes of the electrode assembly 9 discussed below.

[00010] A flight tube 27 positioned between two poles (only one shown) of the mass analysing magnet 5, receives the ion beam from the beam generator 3 and controls the transport energy of the ion beam during its passage between the poles of the magnet 5. The transport energy of the ion beam is a function of the potential difference between the flight tube 27 and the ion source 15. In this particular

embodiment, the magnetic field strength of the analysing magnet and the energy of the ion beam through the magnet are chosen so that ions having an appropriate mass are deflected through approximately 90 degrees for passage through the ion selector 7, the electrode assembly 9 and the electron generator 13 to the surface of the wafer.

[00011] The extraction electrode assembly 20 is shown partially unassembled in FIG. 2. The extractor electrode 21 includes an electrically conductive mounting or support frame component 21a and an electrically conductive insert member component 21b which is inserted into and mounted to the support frame component 21a. In a similar fashion, the extraction electrode 23 includes a support frame component 23a and an insert member component 23b which is inserted into and mounted to the support frame component 23a. In accordance with one aspect of the illustrated embodiments, each insert member component 21b, 23b has a plurality of kinematic alignment pins 29a, 29b (FIG. 2) and 29c, 29d (FIG. 3), respectively. As best seen in the cross-sectional assembly drawing of FIG. 4, the kinematic alignment pins 29a and 29b of the insert member component 21b each have a generally cylindrical body portion 31. In a similar manner, the kinematic alignment pins 29c and 29d of the insert member component 23b each have a generally cylindrical body portion 31 as best seen in the cross-sectional assembly drawing of FIG. 5.

[00012] The insert member component 21b has a plate portion 33a from which the kinematic alignment pins 29a, 29b extend. Also extending from the plate portion 33a is an extraction electrode body portion 35a which defines a pair of ion beam extraction slots 37a, 37b. When mounted to the support frame component 21a, the extraction electrode body portion 35a extends through a central aperture 39 of the support frame component 21a. Similarly, the insert member component 23b has a plate portion 33b from which the kinematic alignment pins 29c, 29d extend. Also extending from the plate portion 33b is an extraction electrode body portion 35b which defines a pair of ion beam extraction slots 37c, 37d. When mounted to the support frame component 23a, the extraction electrode body portion 35b extends through a central aperture 67 of the support frame component 21a.

[00013] The support frame components 21a and 23a are first aligned within the ion implanter 1 and then fastened to suitable mounts indicated schematically at 40a, 40b, respectively in FIG. 2. In some applications, the mounts 40a, 40b include actuators which can move the extraction electrodes 21, 23 such that the ion beam passes through either one set of extraction electrode apertures 37a, 37c or the other set of extraction electrode apertures 37b, 37d, depending upon the application. The

support frame components 21a, 23a may be aligned using a suitable alignment jig or tool which has alignment pins which engage appropriate alignment apertures such as an aperture 42 of the support frame component 21a and appropriate apertures in the electrode mount 40b. Once the support frame components 21a, 23a are aligned with respect to the mounts 40a, 40b, the support frame components 21a, 23a are fastened to the mounts 40a, 40b using suitable fasteners such as screw fasteners. The alignment jib is removed from the ion implanter 1 once the extraction electrode support frame components 21a, 23a are aligned and installed in the ion implanter.

[00014] It is anticipated that the useful lifetime of the support frame components 21a, 23a will be relatively long as compared to the insert member components 21b, 23b. Accordingly, replacement and alignment of the support frame components 21a, 23a using an alignment jig may be relatively infrequent.

[00015] To kinematically mount the insert member component 21b into a previously aligned support frame component 21a, the kinematic alignment pin 29a of the insert member component 21b is received in a kinematic groove 41 (FIG. 4) defined by a portion of the central aperture 39 of the support frame component 21a. When the outer cylindrical surface 31a of the kinematic alignment pin 29a is fully engaged with the surfaces of the kinematic groove 41, the center axis 31b is precisely located in two orthogonal directions relative to the support frame component 21a as represented by the x and y axes of the support frame component 21a of FIG. 4.

[00016] The insert member component 21b is then rotated, pivoting on the axis 31b of the pin 29a until the second kinematic alignment pin 29b of the insert member component 21b engages a flat kinematic alignment surface 43 defined by a portion of the central aperture 39 of the support frame component 21a. When the outer cylindrical surface 31a of the kinematic alignment pin 29b is fully engaged with the flat kinematic alignment surface 43, the center axis 31b of the kinematic alignment pin 29b is precisely located in a rotational direction relative to the support frame component 21a as represented by rotation axis R of the support frame component 21a of FIG. 4. Because the alignment surface 43 is not a groove like the alignment groove 41, the engagement of the pin 29b with the alignment surface 43 does not interfere with the engagement of the alignment pin 29a with the alignment groove 41.

[00017] As shown in FIG. 6, the kinematic alignment pins 29a, 29b each have retainer caps 45 at the ends of the cylindrical body portions 31. As best seen in FIG. 7, the retainer caps 45 are wider in width than the body portions 31 of the kinematic alignment pins such that the caps 45 overhang the pin body portions 31 to provide a

retention flange 45a. The cap retention flange 45a and body portion 31 of each alignment pin together with the opposing adjacent surface of the insert member plate portion 33b forms a retainer groove 47 which receives a tongue portion of the support frame component 21a to secure the insert member plate portion 33b to the support frame component 21a in the third orthogonal direction as represented by the Z axis of the support frame component 21a of FIGs. 4 and 7. For example, the retainer groove 47 of the alignment pin 29b receives a tongue portion 49a of the support frame component 21a. The leading edge 43 of the support frame tongue portion 49a provides the kinematic alignment surface 43 engaged by the outer cylindrical surface 31a of the kinematic alignment pin 29b. In this position, a flat face portion 48 of the insert member plate portion 33a is engaged face to face with a flat face portion 50 of the support frame 21a. In addition to being located and retained in the Z direction relative to the support frame component 21a, the insert member component 21b also makes electrical contact with the support frame component 21a in this engaged position.

[00018] In a similar fashion, the retainer groove 47 of the kinematic alignment pin 29a receives a tongue portion 49b (FIG. 6) of the support frame component 21a to secure the insert member plate portion 33b to the support frame component 21a in the Z direction of FIGs. 2 and 7. The leading edges 41 (FIG. 4) of the support frame tongue portion 49b provides the kinematic alignment groove 41 engaged by the outer cylindrical surface 31a of the kinematic alignment pin 29a.

[00019] In the illustrated embodiment, the insert member component 21b has an additional pin 51 which has an overhanging retainer cap 53 at the end of a generally cylindrical body portion 55 (FIG. 4) to form a retainer groove which receives a tongue portion 49c of the support frame component 21a. The pin 51 acts to further secure the insert member plate portion 33b to the support frame component 21a in the Z direction of the support frame component 21a of FIG 2. The body portion 55 has a relieved portion 55a to provide clearance between the outer surface of the pin body portion 55 so that the pin 51 does not interfere with the kinematic seating of the kinematic alignment pins 29a, 29b.

[00020] The central aperture 39 of the support frame component 21a has recessed portions 39a, 39b, 39c (FIG. 6) which are sized sufficiently to admit the caps 45, 53 of the pins 29a, 29b, 51 into the aperture 39. In addition, the central aperture 39 is sized sufficiently to admit the extraction electrode body portion 35a into the aperture 39. The insert member component 21b is then pushed downward (-Y direction of FIG. 6) until the kinematic alignment pins 29a, 29b engage the

kinematic alignment groove 41 and kinematic alignment surface 43, respectively, as discussed above. The insert member component 21b has a spring 61a (FIG. 2) which engages the support frame component 21a to prevent accidental displacement of the insert member component 21b from the kinematic engagement positions.

[00021] The insert component 23b is kinematically mounted to the support frame component 23a in a similar fashion. Thus, the insert member component 23b has a plate portion 33b from which the kinematic alignment pins 29c, 29d extend. Also extending from the plate portion 33b is an extraction electrode body portion 35b which defines a pair of ion beam extraction slots 37c, 37d. When mounted to the support frame component 23a, the extraction electrode body portion 35b extends through a central aperture 67 of the support frame component 23a

[00022] To kinematically mount the insert member component 23b into a support frame component 23a which has previously been aligned using an alignment tool as described above in connection with the support frame component 21a, the kinematic alignment pin 29c of the insert member component 23b is received in a kinematic groove 41 (FIG. 5) defined by a portion 67a of the central aperture 67 of the support frame component 23a. When the outer cylindrical surface 31a of the kinematic alignment pin 29c is fully engaged with the surfaces of the kinematic groove 41, the center axis 31b is precisely located in two orthogonal directions relative to the support frame component 23a as represented by the x and y axes of the support frame component 23a of FIG. 5.

[00023] The second kinematic alignment pin 29d of the insert member component 23b is then rotated until it engages a flat kinematic alignment surface 43 defined by a portion 67b of the central aperture 67 of the support frame component 23a. When the outer cylindrical surface 31a of the kinematic alignment pin 29d is fully engaged with the flat kinematic alignment surface 43, the center axis 31b of the kinematic alignment pin 29d is precisely located in a rotational direction relative to the support frame component 23a as represented by rotation axis r of the support frame component 23a of FIG. 5.

[00024] In a fashion similar to that of the electrode 21, the retainer grooves of the kinematic alignment pins 29c, 29d receive tongue portions 49c, 49d (FIG. 3) of the support frame component 23a to secure the insert member plate portion 33b to the support frame component 23a in the z direction of FIG. 2. However, rather than using an additional pin such as the pin 51, the insert member plate portion 33b has a retainer tab 69 which receives a tongue portion 49e of the support frame component 23a to further secure the insert member plate portion 33b to the support frame

component 23a in the z direction of FIG. 2. The insert member component 23b has a spring 61b (FIGs. 2, 3) which engages the support frame component 23a to prevent accidental displacement of the insert member component 23b from the kinematic engagement positions. As best seen in FIG. 5, the spring 61b has ends received in apertures 70 of the insert member 23a to position the spring 61b to bias the insert member component 23b in the retained position.

[00025] It is appreciated that by locating the kinematic alignment grooves 41 and kinematic alignment surfaces 43 in known positions on the electrode support frames 21a, 23a, and by locating the kinematic alignment pins 29a, 29b, 29c, 29d in known positions of the insert member components 21a, 23b, the extraction electrode apertures 37a, 37b, 37c, 37d may be kinematically aligned with respect to the electrode support frames without the use of separate alignment tools. Moreover, the use of time consuming fasteners such as screws to fasten the insert member components 21b, 23b to the support frame components 21a, 23a may be eliminated if desired.

[00026] In the illustrated embodiment, the support frame components 21a, 23a and the insert member components 21b, 23b are each fabricated as integral, one-piece member components. Thus, for example, the kinematic alignment pins 29c, 29d, the insert member plate portion 33b, and the extraction electrode body portion 3b of the insert member component 23b are fabricated integrally into a one-piece member. Each component may be fabricated as a cast member in a mold and machined to the final dimensions, or may be fabricated as separate parts and welded, brazed or otherwise combined together into the desired component. It is appreciated that each component may also be fabricated from separate parts fastened together. However, it is believed that an integral, one-piece construction of each component may facilitate placement of the kinematic surfaces in the appropriate locations.

[00027] As previously mentioned, the kinematic mounting arrangement of the illustrated embodiments may be applied to ion implanter electrodes other than extraction electrodes. For example, as shown in FIG. 1, the ion selector 7 of the illustrated embodiment, comprises a series of discrete elements 135, 139, 141 and 143 which are spaced apart along the beamline 145 and define a series of apertures which, in combination, select ions of the correct mass to be implanted in the target substrate while rejecting other spatially resolved ions which pass through the analyzing magnet 5. In this particular embodiment, the ion selector 7 comprises a plate electrode 135 which rejects most of the unwanted ion species exiting from the

magnet, a pair of elements 139, 141, which together define a variable width mass resolving slit which passes only the selected ion specie, and a further element 143 which defines the height of the ion beam. However, the number of mass resolving elements and their configuration may be varied.

[00028] The ion selector assembly is housed in a chamber 147 which forms part of the flight tube 27 and which is disposed between the magnet and the electrode assembly 9. The flight tube 27 including the mass resolving chamber 147 provides the means by which the beam is transported from the ion beam generator to the electrode assembly 9. The mass resolving chamber wall 149 comprises a part 151 which extends in the direction of the beamline and defines a generally cylindrical envelope, and a transverse part 153 adjacent the cylindrical part 151 which constitutes a plate electrode disposed transverse to the beam line and defines an aperture 155 through which the beam can pass, the aperture 155 being adjacent the final element 143 of the ion selector 7. The transverse part 153 provides an electromagnetic screen for screening the ion selector 7 from electric fields originating downstream of the ion selector. The kinematic mounting techniques described herein may be applied to one or more of the plate electrodes of an ion selector of an ion implanter.

[00029] A screening assembly 152 is positioned between the exit aperture 155 of the mass resolving chamber 147 and the electrode assembly 9 to reduce penetration of the electric field from the electrode assembly 9 into the mass resolving chamber 147 through the exit aperture 155. The screening assembly 152 comprises a cylindrical electrode 154, and a field defining electrode 156. The cylindrical electrode 154 is arranged coaxially with the exit aperture 155 of the mass resolving chamber and with one end positioned adjacent and connected to the transverse part (or front end) 153 of the mass resolving chamber wall 149. The cylindrical electrode 154 extends forward of the mass resolving chamber 147 and may have an inwardly extending radial flange 160 formed near or at the other end of the cylindrical electrode 154 to provide additional screening, and defining an exit aperture 162.

[00030] The field defining electrode 156, which may or may not be used, comprises a circular plate with an aperture 164 formed in the center thereof. The field defining electrode 156 is mounted within and supported by the cylindrical electrode 154 and is positioned about midway between the ends of the cylindrical electrode 154 (although this may vary) and transverse to beam line 145. The aperture 164 is preferably rectangular or square and, in one embodiment may taper gently outwards towards the electrode assembly 9. In this example, the aperture is square and has a

width of about 60 mm. The cylindrical electrode 154 and the field defining electrode 156 may each be made of graphite or other suitable material. The kinematic mounting techniques described herein may be applied to the electrodes of a screening assembly of an ion implanter.

[00031] The electrode assembly 9 for controlling the implant energy of the ion beam is situated just beyond the screening assembly 152, and comprises a field or ring electrode 161 and an apertured plate electrode 165. The field electrode 161, has a generally circular symmetry and defines an aperture 163 adjacent and substantially coaxial with the exit aperture 164 of the screening assembly 152. The plate electrode 165 is disposed generally transverse to the beamline 145 and defines a further aperture 167 through which the ion beam can pass, this further aperture 167 being disposed adjacent the field electrode aperture 163. The diameter of the field electrode and plate electrode apertures are about 90 mm and 80 mm, respectively, in this example. The field electrode and the plate electrode may each be made of graphite or other suitable material. The kinematic mounting techniques described herein may be applied to the electrodes of an ion selector for controlling implant energy.

[00032] In this embodiment, the electron injector 13 comprises a plasma flood system which introduces low energy electrons into the ion beam near the target. The plasma flood system includes a guide or confinement tube 169 through which the ion beam can pass from the plate electrode aperture 167 to the target substrate 12, and which both maintains electrons from the plasma flood system in the vicinity of the ion beam and screens the portion of the ion beam between the plate electrode aperture and the wafer from stray electric fields. An apertured plate electrode 170 is positioned at the upstream end of the confinement tube, adjacent the apertured plate electrode of the deceleration assembly to provide additional screening of the interior of the confinement tube from electric fields from the field electrode 161. The kinematic mounting techniques described herein may be applied to the electrodes of an electron injector of an ion implanter. The kinematic mounting techniques described herein may be applied to the electrodes of a plasma flood system of an ion implanter.

[00033] In this embodiment, the ion implanter further comprises an ion source voltage supply 171 for biasing the ion source, a suppression electrode voltage supply 173 for biasing the suppression electrode 21, a flight tube voltage supply 175 for biasing the flight tube 27, the mass resolving chamber 147, the screening assembly 152, and the other extraction electrode 23, a field electrode voltage supply 177 for

biasing the field electrode 161 of the electrode assembly 9, and a plasma flood voltage supply 179 for biasing the electron confining electrode 169 and the apertured screening plate electrode 170. In this embodiment, the apertured plate electrode 165 of the deceleration lens, the target substrate holder 11 and the substrate 12 are maintained at ground potential, which facilitates handling of the target substrate, simplifies the target support assembly, and serves as a convenient reference potential for the other electrodes.

[00034] In this particular embodiment, a vacuum port 157 is formed in the chamber wall 149 near the analysing magnet 5 which is connected to a vacuum pump 159 for evacuating the chamber 147, although in another embodiment this vacuum port may be omitted.

[00035] The foregoing description of various embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. For example, it is appreciated that the shapes and sizes of the various alignment and retention surfaces may vary, depending upon the application. It is intended that the scope of the invention not be limited by this detailed description.